Preliminary Report on the Marquesan Sardine, *Harengula vittata,* in Hawaii

THOMAS S. HIDA and ROBERT A. MORRIS[1]

THE MARQUESAN SARDINE, *Harengula vittata,* was introduced to Hawaiian waters in eight plantings from 1955 through 1959 by the Bureau of Commercial Fisheries in an attempt to establish this species as a supplementary bait fish for skipjack fishing. The details of the first seven introductions have been reported by Murphy (1960) and the eighth by Brock (1960). The eighth introduction comprised an estimated 4,000 sardines ranging from 7.0 to 9.4 cm in standard length[2] and averaging 8.2 cm. This brought the estimated total number of sardines introduced to Hawaii to 144,000. All of the releases have been made around the island of Oahu (Fig. 1).

SOURCES OF INFORMATION

The introduction of the sardines was publicized by means of posters and letters. Commercial and sport fishermen and game wardens were asked to cooperate in supplying information on sightings and captures. Jars of formalin and labels for recording data concerning captures were supplied to the game wardens and the skipjack fishermen, whose bait nets were considered a likely source of specimens. From 1956 through 1960, 54 samples comprising 336 fish were turned in, the majority of them by skipjack fishermen.

DISTRIBUTION

Recaptures of Marquesan sardines have been reported from six of the eight major islands in Hawaii (Fig. 2). The lack of reports from Lanai and Niihau may be due to the fact that skipjack fishermen rarely fish for bait in the waters around those islands.

Table 1 lists all the sardine recoveries from the Hawaiian Islands. The first recapture was made in Keehi Lagoon, Honolulu, in 1956. Subsequent recoveries were from Barber's Point and Kaneohe Bay, Oahu, in 1957. In 1958 sardines were taken at the islands of Kauai and Maui, where no releases had been made, and also in Honolulu Harbor and Pearl Harbor, Oahu, for the first time. In 1959 the sardine was reported from the islands of Hawaii and Kahoolawe, and for the first time from Haleiwa, Oahu. The first specimens from Molokai and from Nawiliwili and Hanamaulu bays, Kauai, came in 1960. Sardines have been taken from both the leeward and windward shores of Oahu and Kauai but only from the leeward shores of Hawaii, Maui, Kahoolawe, and Molokai (Fig. 2).

Neither our knowledge of the life history of this species nor our observations of it in Hawaiian waters are adequate to tell us whether the extension of its distribution from Oahu to the other islands has come about through migration of the adults across the channels or through the drifting of eggs or larvae with the currents.

The habitat occupied by the sardine seems to coincide with that of the nehu, *Stolephorus purpureus,* the most commonly used tuna bait fish in Hawaii. This distribution pattern may be only a sampling artifact, since most of the fishing with gear likely to take sardines is done by skipjack fishermen fishing for nehu. However, because of the chronic shortage of tuna bait in Hawaii, the fishermen are alert for reports of bait supplies even in areas outside the usual nehu fishing grounds. If sardines were present in conspicuous abundance in any accessible area, it appears highly probable that the fishermen

[1] U. S. Bureau of Commercial Fisheries Biological Laboratory, Honolulu, Hawaii. Manuscript received May 21, 1962.

[2] All of the length measurements appearing in this report are expressed in standard length, which is the distance from the tip of the snout to the end of the hypural.

TABLE 1

RECORDS OF MARQUESAN SARDINES COLLECTED IN HAWAII

LOCALITY	DATE OF CAPTURE	METHOD OF CAPTURE	NUMBER CAUGHT	NUMBER PRESERVED	STANDARD LENGTH (cm)	
					Range	Mean
Oahu I.						
Keehi Lagoon	9/27/56	night net[1]	....	1	9.97–	9.97
	3/27/57	night net[1]	....	1	8.50–	8.50
	10/4/59	night net[1]	est. 500	17	3.59–5.60	4.40
	11/3/59	night net[1]	....	7	5.25–5.68	5.46
	11/5/59	night net[1]	....	27	4.08–6.07	4.88
	11/25/59	night net[1]	....	16	4.03–6.46	5.51
	12/1/59	(?)	....	2	3.05–3.51	3.28
	7/20/60	day seine	est. 3	1	2.92–	2.92
	9/14/60	day seine	....	3	3.39–4.72	4.27
Kaneohe Bay	3/26/57	day seine	est. 7	1	8.75–	8.75
	4/8/57	night net	....	4	8.07–8.75	8.46
	6/4/57	night net	....	1	9.50–	9.50
	6/30/58	(?)	....	1	9.75–	9.75
	9/23/58	day seine	....	1	5.60–	5.60
	11/3/58	day seine	....	1	3.46–	3.46
	11/27/58	day seine	est. 12	6	3.53–4.30	3.96
	7/20/59	day seine	16	8	4.30–13.21	7.66
	9/4/59	day seine	....	2	4.90–8.56	6.73
	9/6/59	day seine	....	2	3.04–3.22	3.13
	9/11/59	day seine	....	1	8.30–	8.30
	9/14/59	day seine	....	2	8.21–8.67	8.44
	10/2/59	day seine	....	1	5.40–	5.40
	2/26/60	day seine	....	1	12.01–	12.01
	6/9/60	day seine	....	2	3.34–3.68	3.51
Barbers Point	9/9/57	gill net	....	6	11.20–13.50	12.55
Honolulu Harbor	2/28/58	night net	....	4	7.71–9.40	8.72
	6/27/58	night net	....	1	9.54–	9.55
Pearl Harbor	4/29/58	day seine	....	3	10.05–10.71	10.45
Haleiwa	9/2/59	day seine	....	11	4.46–6.10	5.27
	6/22/60	day seine	est. 20	5	3.98–5.14	4.54
	7/22/60	day seine	....	2	4.71–8.64	6.67
Maui I.						
Kihei	7/5/58	(?)	1	10	not exam.	not exam.
	10/7/58	day seine	....	29	3.49–5.32	4.67
	11/3/58	day seine	....	4	6.32–7.00	6.59
	5/19/59	day seine	est. 6	1	9.12–	9.12
	5/28/59	day seine	....	7	9.10–10.91	9.91
	5/29/59	day seine	....	2	9.29–10.83	10.06
	6/2/59	day seine	....	1	8.56–	8.56
Maalaea Bay	8/13/59	day seine	....	3	5.62–6.00	5.87

[1] The net used in Hawaii for taking tuna bait at night is a rectangular lift net pulled under the fish which are attracted to an underwater light suspended alongside the fishing boat.

[2] A "bucket" of bait in the Hawaiian skipjack fishery is estimated to represent about 7 lb of fish.

TABLE 1—*Continued*

LOCALITY	DATE OF CAPTURE	METHOD OF CAPTURE	NUMBER CAUGHT	NUMBER PRESERVED	STANDARD LENGTH (cm)	
					Range	Mean
Kauai I.						
Port Allen	9/10/58	night net	....	6	6.17–6.69	6.41
	10/2/58	night net	....	6	3.90–7.90	6.60
	5/24/60	day seine	est. 100	3	3.80–7.34	5.05
	7/5/60	day seine	est. 500	10	4.00–6.87	5.45
	7/9/60	day seine	est. 100	58	5.85–8.75	7.24
	7/23/60	day seine	est. 20	7	4.67–5.99	5.54
Hanalei Bay	9/25/58	(?)	....	6	6.90–7.90	7.50
Waimea Bay	1/?/59	pole-and-line	....	2	9.80–11.48	10.64
	10/14/59	pole-and-line	....	1	14.62–	14.62
	7/23/60	day seine	est. 40	2	11.34–13.30	12.32
Nawiliwili Harbor	6/2/60	night net	....	8	10.57–12.47	11.75
Hanamaulu Bay	9/6/60	gill net	....	1	12.21–	12.21
Hawaii I.						
Kawaihae Bay	3/14/59	day seine	est. 3 bkts.[2]	12	7.56–10.05	8.73
Kahoolawe I.						
SW Point	6/17/59	day seine	est. ½ bkt.	11	9.76–12.08	10.83
Molokai I.						
Laau Point	9/3/60	day seine	....	5	5.61–6.70	5.80

would find them. The main nehu baiting areas are in the relatively protected waters of bays, harbors, and canals where the water is brackish and turbid owing to the influx of streams and ground water. The Kihei area on the island of Maui and Waimea on Kauai are exceptions, the baiting grounds being exposed to the open ocean and moderate surf action. Baiting, in general, is done close to shore in shallow water, although night-lighting for bait may be done in deeper waters of channels and harbors. Since it appears that the sardine has established itself in the nehu grounds, it is important, from the standpoint of the tuna fishery, to keep a close watch on the population trend of the species in Hawaii and the effect that it may have on the bait supply in the future.

ABUNDANCE

Our only source of information on the abundance of sardines in Hawaiian waters has been the reports of observations by commercial and sport fishermen. The numbers of specimens turned in by fishermen are not a good index of abundance, because often they are only a small and arbitrarily selected fraction of the catch. There have also been times when sardines were seen but not caught.

The first observation of a large school of sardines, 20 to 30 buckets,[3] was made in Waimea, Kauai, late in the summer of 1958 by skip-

[3] A "bucket," the unit commonly used by skipjack fishermen for measuring bait, contains an average of 7 lb of fish.

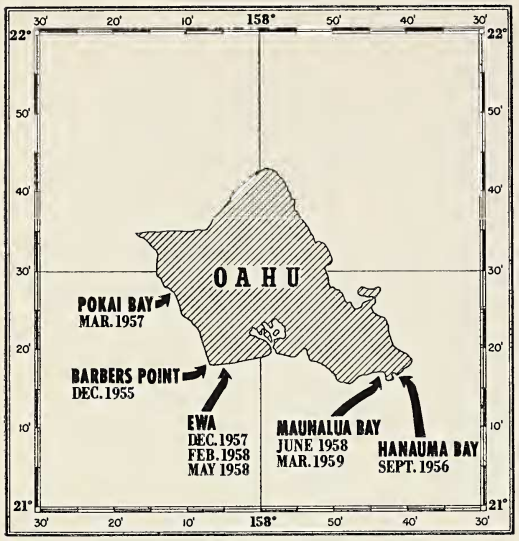

FIG. 1. Map of Oahu showing areas where sardines have been released.

jack fishermen. The school remained in Waimea Bay until January 1959; its disappearance from the Bay coincided with a storm which occurred in that month. In March, 1959, a skipjack boat caught 3 buckets of sardines at Kawaihae, Hawaii, and reported catching 900 lb of skipjack with them, a bait-catch ratio comparable to that ordinarily obtained using nehu. The fishermen commented that the sardines were an excellent bait. In October, 1959, an estimated 500 sardines were caught in Keehi Lagoon, Oahu, by skipjack fishermen. These were used for bait, but no report was submitted on the results. The latest report of sizeable sardine catches came from Port Allen, Kauai, where a catch of 100 sardines was made in May, 1960, and a catch of 500 sardines and another of 100 was made in July, 1960. Aside from these few instances of fairly large catches, most of the reports from the fishermen have indicated that the sardine was taken or sighted only in small numbers. Thus, although the sardine appears to be well established in Hawaii, it is apparently not abundant, at least not in areas frequented by fishermen, and is not as yet making any significant contribution as a bait fish.

FOOD

We examined the stomach contents of 132 sardines caught in Hawaii to study their food habits in their new environment. This examination covered samples representative of all areas from which specimens had been turned in. Only fish with identifiable food organisms were included in the analysis. We did not consider as food items nematodes, wood, and other foreign matter, or material which we could not readily identify. Thirty-nine (30%) of the stomachs examined were considered to be empty. This high percentage of empty stomachs was probably due to the fact that many of the fish had been held captive for several days in baitwells.

In terms of the percentage frequency of occurrence of various organisms in the stomachs of all samples (Table 2), copepods were first, followed by gastropod larvae, adult and larval shrimp, crab larvae, fish larvae, amphipods, and polychaetes. Copepods were also observed in the greatest numbers.

The following list of the numbers and kinds of organisms found in the well-distended stomach of a 9.4-cm sardine caught at Kihei, Maui, represents the quantity and variety of food that may be taken by this fish:

689 copepods	24 lucifers
34 amphipods	7 ostracods
30 shrimp larvae	3 crab megalops
27 crab zoeae	3 stomatopod larvae
	1 unidentified fish larva

In contrast, the stomach of another 9.4-cm sardine appeared filled to capacity with three nehu larvae about 3 cm long.

Of the fish examined, 50% were between 3.5 and 6.0 cm long, the rest ranging up to 14.5 cm.

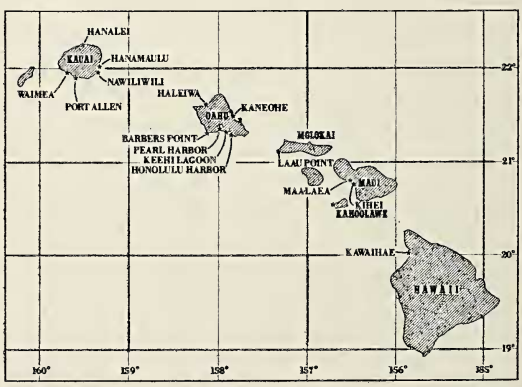

FIG. 2. Map of the Hawaiian Islands showing the areas from which sardines have been recovered.

TABLE 2

PERCENTAGE FREQUENCY OF OCCURRENCE OF VARIOUS ORGANISMS IN THE STOMACHS OF 93 SARDINES

LOCALITY (No. of fish examined)	COPEPODA	GASTROPOD LARVAE	SHRIMP ADULTS & LARVAE	CRAB LARVAE	FISH LARVAE	AMPHIPODA	POLYCHAETA	BARNACLE CYPRIS	STOMATOPOD LARVAE	HETEROPODA (*Atlanta* sp.)	LUCIFER	PELECYPOD LARVAE	CHAETOGNATHA	OSTRACODA	ISOPODA	INSECT LARVAE	MYSIDACEA	PTEROPODA	CLADOCERA
Oahu I.																			
Honolulu Harbor (3)	67	....	....	33	....	....	33	....	....	....	....	....	....	....	....	....	....	....	....
Haleiwa (12)	100	50	8	....	....	25	50	....	....	....	....	17	....	....	8	8	8	....	....
Kaneohe Bay (16)	94	31	38	31	12	12	25	31	12	....	....	6	....	....	6	....	....	....	6
Barbers Point (5)	60	20	60	80	....	20	....	....	....	....	....	....	....	....	20	....	20	....	....
Keehi Lagoon (12)	100	....	17	33	8	17	17	....	8	....	17	....	8	17	....	....	....	....	....
Maui I.																			
Kihei (15)	73	33	20	13	27	7	....	7	20	....	....	....	13	7	....	7	....	....	....
Hawaii I.																			
Kawaihae Bay (8)	12	....	....	....	100	....	12	....	....	....	....	....	....	....	....	....	....	....	....
Molokai I.																			
Laau Point (5)	100	....	20	40	....	80	....	20	40	....	100	....	....	....	....	20	....	....	....
Kahoolawe I.																			
SW Point (10)	100	40	80	20	....	10	....	10	....	80	....	10	20	....	....	....	....	20	....
Kauai I.																			
Port Allen (6)	83	83	....	67	....	33	....	....	....	....	....	33	....	17	17	....	....	....	....
Waimea Bay (1)	....	....	....	....	100	....	....	....	....	....	....	....	....	....	....	....	....	....	....
All areas combined	82	28	26	26	17	17	15	9	9	9	8	6	5	4	4	3	2	2	1

The food habits of the larger and smaller sardines appeared to be essentially similar, but fish larvae were found only in sardines 8.0 cm long or larger, and there seemed to be a size-associated difference in the composition of the copepod component of the diet. The smaller fish fed more commonly on small cyclopoid copepods, such as *Corycaeus* sp. and *Oncaea* sp., while the larger sardines had more often been feeding on larger calanoids, such as *Candacia* sp., *Labidocera* sp., and *Pleuromamma* sp. The samples were inadequate to carry on a detailed study of food habits among the different areas.

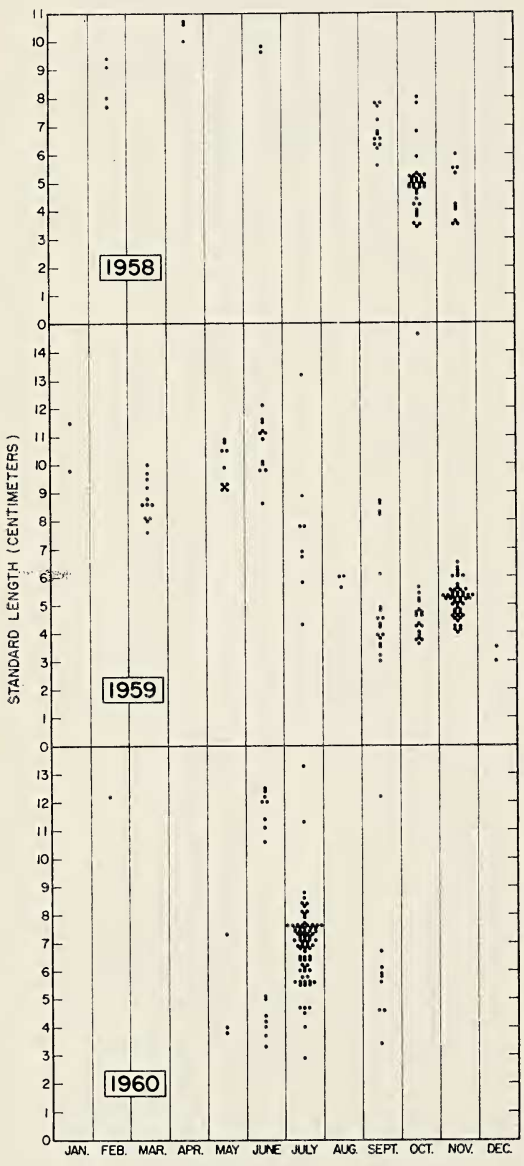

FIG. 3. Size frequencies of sardines collected in Hawaii in 1958, 1959, and 1960.

As indicated in Table 2, 17% of the stomachs with food had fish larvae in them. Of 34 fish larvae found, 24 (71%) were identified as nehu. The largest number of larval nehu found in a stomach was 6, in a 10.8-cm specimen from Kihei, Maui. The largest nehu found measured 3.3 cm, in a 9.4-cm sardine, also from Kihei, Maui.

The food habits of *H. vittata* in its native environment were extensively studied by Nakamura and Wilson (MS). They also found copepods to be the most frequently occurring organism (79.1%), followed by pelecypods, gastropods, barnacle cypris, pteropods, amphipods, and megalops. Fish larvae occurred in only 1.6% of the stomachs. The only distinct difference between the feeding habits of the species in Hawaii and in the Marquesas seems to be the low percentage of occurrence of fish larvae in the Marquesan fish.

The food habits of the sardine in Hawaii are similar to those of the nehu, both species feeding largely on the crustacean elements in the plankton. Hiatt (1951) found that nehu feed primarily on copepods, barnacle larvae, mysis larvae of shrimps, ghost shrimp (*Lucifer* sp.), crab larvae, and palaemonid shrimps.

SPAWNING

The size of the first sardines taken at Maui and Kauai in 1958 was such that, as pointed out by Murphy (1960), it seemed more likely that they were the products of spawning in Hawaiian waters rather than members of the original transplanted stock. A collection of 29 sardines taken at Kihei, Maui, in October, 1958, contained 7 measuring less than 4.3 cm, which was the length of the smallest sardine measured in the release of May, 1958. Subsequently, sardines smaller than 4.3 cm were taken in Keehi Lagoon and Kaneohe Bay in July, September, October, November, and December, 1959 (Fig. 3). In 1960, small sardines were caught at Keehi Lagoon, Kaneohe Bay, and Haleiwa on Oahu, and at Port Allen, Kauai, in May, June, July, and September.

Nakamura and Wilson (ms) have reported that in the Marquesas 8.4 cm, plus or minus 1.7 cm, is the mean length of females at sexual maturity. They considered that year-round occurrence of ovarian eggs of 0.6 mm or larger diameter indicated that sardines spawn throughout the year in Marquesan waters. Although our Hawaiian samples were inadequate for determination of the spawning season of the introduced fish, the occurrence of ova 0.43 to 0.74 mm in diameter in sardines taken in May, June, July, September, and October and the appearance of small sardines from May through December lead us to believe that the species also has a prolonged spawning period in Hawaii.

SUMMARY

Eight releases of the Marquesan sardine, *Harengula vittata,* have been made around the island of Oahu in the hope that it would become established and sufficiently abundant to increase the tuna bait fish supply. An estimated 144,000 individuals were released from 1955 through 1959. Recoveries by skipjack fishermen have been made from all of the major islands except two. The habitat occupied by the sardine seems to coincide with that of the most important native bait fish, the nehu (*Stolephorus purpureus*). The occurrence of young sardines since 1958 indicates that they have spawned successfully, but the species is not yet making any significant contribution as a bait fish. The sardines feed primarily on copepods, and also eat gastropod larvae, larval and adult shrimps, crab larvae, fish larvae, amphipods, and polychaetes. This diet is similar to that of the nehu.

REFERENCES

Brock, Vernon E. 1960. The introduction of aquatic animals into Hawaiian waters. Int. Rev. Hydrobiol. 45(4):463–480.

Hiatt, Robert W. 1951. Food and feeding habits of the nehu, *Stolephorus purpureus* Fowler. Pacif. Sci. 5(4):347–358.

Murphy, Garth I. 1960. Introduction of the Marquesan sardine, *Harengula vittata* (Cuvier and Valenciennes), to Hawaiian waters. Pacif. Sci. 14(2):185–187.

Nakamura, Eugene L., and Robert C. Wilson. ms. The distribution and biology of the Marquesan sardine. Bu. of Comm. Fish. Bio. Lab., Honolulu.